FLIGHT TELEMETRY

FLIGHT TELEMETRY

2409

INSTRUCTIONS AND APPLICATIONS

Electronic Voltmeter Type 2409

An instrument for the measurement of the peak, arithmetic average and true R.M.S. value of a.c. voltages in the frequency range 2—200ooo c/s. Voltage range from 10 mV to 1ooo Volt full scale deflection in 10 db steps. The high input impedance, low output impedance and accurately calibrated input attenuator make this an ideal instrument for use also as a calibrated amplifier with a maximum gain of 60 db.

- Acoustic standing wave apparatus
- Artificial ears
- Artificial voices
- Audio frequency spectrometers
- Audio frequency voltmeters
- Automatic A. F. spectrum recorders
- Automatic frequency response recorders
- Beat frequency oscillators
- Condenser microphones
- Deviation bridges
- Distortion measuring bridges
- Electronic counters
- Frequency analyzers
- Frequency measuring bridges
- Frequency response tracers
- Hearing aid test apparatus
- Heterodyne voltmeters
- Level recorders
- Megohmmeters
- Microphone amplifiers
- Microphone calibration apparatus
- Noise sources
- Polar diagram recorders
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- Rotary selectors
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Electronic Voltmeter

Type 2409

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Description

General.

The Electronic Voltmeter Type 2409 is designed for AC voltage measurements in the frequency range 2 c/s to 200ooo c/s, with voltage ranges from 10 mV full scale deflection to 1ooo volts full scale deflection in 10 db steps.

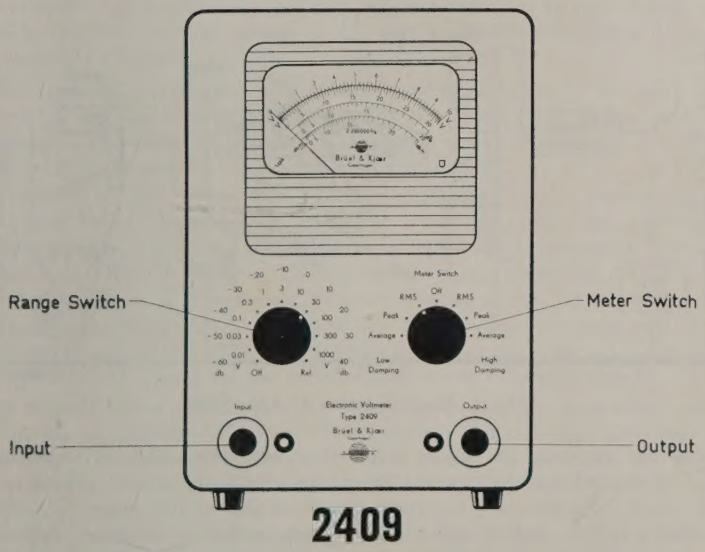

Fig. 1. Electronic Voltmeter Type 2409.

It consists of a two-stage amplifier, rectifying circuits for RMS, average, and peak measurements and a moving coil meter. Furthermore, two different meter damping characteristics can be selected in order to obtain clear and

accurate readings also at low frequencies. The amplifier is provided with an output jack making it possible to use the instrument as calibrated amplifier, the max. amplification being 60 db.

Amplifier and Meter Circuit.

The screened input socket is connected to an attenuator circuit containing 10 steps of 10 db. The eleven measuring ranges are designed to give full deflection for the following voltages: 10 mV, 31.5 mV, 100 mV, 315 mV, 1 V, 3.15 V, 10 V, 31.5 V, 100 V, 315 V, and 1ooo V. The attenuator is divided into two sections, one of which contains two steps of 40 db, the other one containing three steps of 10 db. Both sections are operated by means of a single switch on the front plate of the apparatus. A cathode follower stage is inserted between the two attenuator sections in order to obtain a high input impedance. The input impedance is 10 MΩ parallel to 20 pF. By means of a series capacitor in the grid circuit of the cathode follower the Voltmeter is protected against DC voltages.

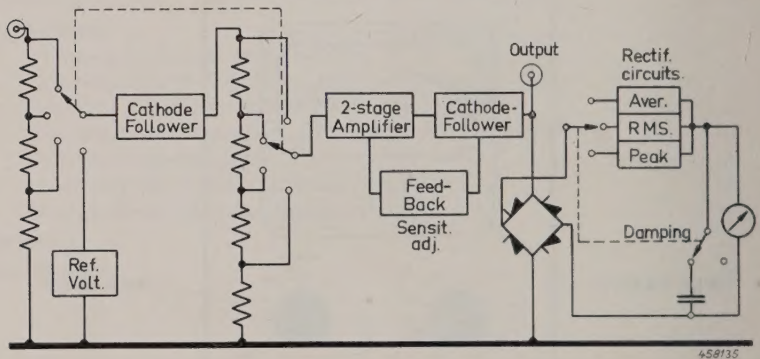

Fig. 2. Block diagram of Type 2409.

From the attenuator the signal is fed to a two stage amplifier, consisting of a triode and a pentode, and followed by a cathode follower providing a low output impedance for the meter circuit as well as the output jack. The amplifier is R-C coupled and is stabilized by means of negative feedback. By means of a potentiometer the amount of negative feedback, and thereby the sensitivity of the instrument, can be varied. The sensitivity potentiometer is accessible through a hole in the back plate of the apparatus and can be adjusted with the aid of a screwdriver.

A second feedback circuit is employed in order to ensure a sharp cut-off right below 2 c/s.

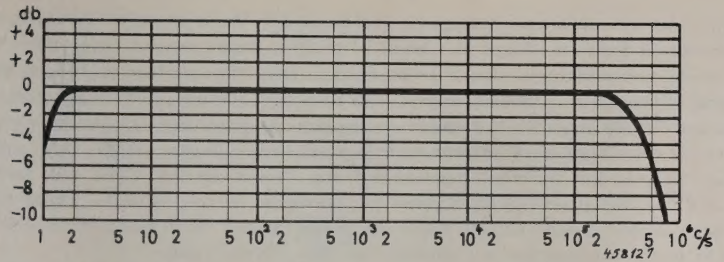

Fig. 3. Typical frequency response of the Electronic Voltmeter Type 2409.

The signal from the output cathode follower is fed to the meter circuit and to an output jack by means of which it is possible to use the instrument as an amplifier for level recorders, oscilloscopes etc. The max. amplification is 60 db and the output impedance is approx. 50 ohms in series with 25 μF. Output voltages up to 30 volts are available without noticeable distortion (less than 1 %). As the meter has full scale deflection for 10 volts output, the "Meter Switch" may be turned to its "off" position when output voltages higher than 10 volts are desired.

The meter circuit consists of a bridge rectifier, a "r.m.s.", "average" and "peak" rectifying circuit, and a moving coil meter. The bridge rectifier employs four germanium diodes in an ordinary graetz arrangement providing full wave rectification of the amplified input signal.

By means of the "Meter Switch" it is possible to choose between three different meter characteristics, whereby either the peak, the arithmetic average or the true r.m.s. value of the input signal can be measured. Furthermore, two different damping characteristics of the meter can be selected, one of which is in accordance with the standards for VU-measurements. (See also appendix page 11). Because this damping characteristic will cause the meter pointer to vibrate at frequencies lower than 20 c/s, a greater damping can be chosen for the measurement of low frequency signals.

The r.m.s. rectifier circuit is designed to approximate the square-law curve by means of a number of straight line portions. The resulting curve enables the true r.m.s. value of signals with crest factors up to 5 (14 db) to be measured to within $\pm$ 0.5 db of the theoretically correct value, (see also appendix page 11).

The peak rectifier circuit is designed to measure *half* the peak-to-peak value of the input signal. This should be borne in mind when peak measurements are carried out on unsymmetrically shaped signals.

The meter itself is a square type moving coil meter. It is illuminated and the scale is gradated in volts from 0 to 10 V and from 0 to 31.5 V as well as in db from 0 to 20 db re 1 volt and furthermore in dbm, which is here defined as db re 0.775 volts (1 mW in 600 ohms).

In order to check and correct the sensitivity of the instrument a reference circuit is built in. When the input attenuator knob on the front plate is turned to its extreme clockwise position, a reference voltage is fed to the grid of the input cathode follower. The reference voltage is developed across a zener-diode, whereby the waveform becomes an approximated square wave. As the wave form is not a pure square wave, the deflection on the meter will be different for different positions of the "Meter Switch". The red mark (8 V) on the scale, which is used for reference, is the value to which the meter pointer should deflect, when the "Meter Switch" is in position "R.M.S.". The meter damping has no influence on the reference point.

Power Supply.

The Electronic Voltmeter can be operated from power lines supplying 115 — 127 — 150 — 220 or 240 volts and at frequencies from 40 to 400 c/s. The power consumption is about 28 watts. Adjustment for the various mains voltages is carried out by means of a switch, which can be operated with the aid of a screwdriver through a hole in the back plate of the instrument cover. A pilot disc indicates to which mains voltage the instrument is adjusted. The instrument is protected by means of a fuse in the primary side of the power transformer. The fuse can be changed when the special fuse-cover on the back plate of the instrument is removed. If it is desired to operate the instrument from a dc power line or from batteries, a converter must be employed to deliver the necessary a.c. voltage.

Operation

1. Make sure that the apparatus is adjusted to the appropriate mains voltage. If not, turn the voltage adjustment switch on the back cover of the apparatus until the desired voltage is indicated on the pilot disc.
2. Connect the instrument to the power line by means of the power cable.
3. Rotate the range switch on the front plate from its "Off" position to its "Ref." position.
4. Allow 1—2 minutes warm-up time. (When very accurate measurements are carried out, the instrument should be allowed to warm-up for about 15 minutes).
5. Set the "Meter Switch" to "R.M.S.".
6. Check that the meter pointer deflects to the red mark on the scale (8 volts). If not, adjust the sensitivity potentiometer on the back cover of the instrument until the meter pointer deflects to the red mark (8 volts).
7. Turn the "Meter Switch" to the desired rectifier characteristic. When measuring low frequency signals (below 20 c/s) the high damping should be used.
8. Turn the range switch to a suitable range.
   The instrument is now ready for use.

Applications

Voltage and Current Measurements.
When the instrument is adjusted to the correct sensitivity as described in the operation procedure on page 6 it can be used for all kinds of a.c. voltage measurements within the stated frequency and voltage ranges.

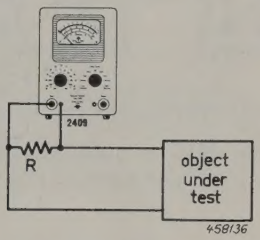

Fig. 4. Current measurement with the aid of an external shunt resistor.

However, with the aid of an external resistor, the instrument may also be used for current measurements. As seen from Fig. 4 the resistor should be connected across the input terminals and the test leads are then applied to the measuring object in the usual way.
When the value of the external resistor is chosen to be 1 ohm, the reading of the meter scale and attenuator is similar to that used for voltage measurements, i.e. when reading 10 mV the current flow is 10 mA and when reading 10 volts, the current flow is 10 Amps. etc. If the value of the external resistor is 10 ohms or 100 ohms, the reading obtained should be devided by 10 or 100 etc. For the measurements of small currents, screening of the external resistance may often be an advantage.

Measurements of Impedance, Inductance, or Capacitance.
Measurements of impedance, inductance, and capacitance can be carried out by means of the Electronic Voltmeter Type 2409 and a Beat Frequency Oscillator, see Fig. 5. As voltage source the B.F.O. Type 1014 is used, and R is a resistance box or standard resistor, the value of which can be read off from a scale. R is then adjusted till the meter indicates the same voltage for both positions of the switch. As the test frequency can be read off from the B.F.O. frequency scale, the size of C_1, can easily be calculated from the formula: $C = \frac{1}{\omega R}$. For accurate measurements it is required that the value of R is small compared to 10 MΩ, which is the input impedance of the Electronic Voltmeter.
The measuring arrangement shown in Fig. 5 may also be used for measurement of inductance of coils, transformer windings etc. The measuring

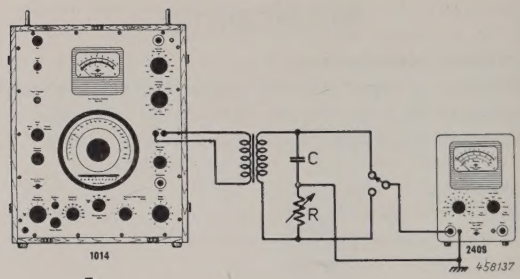

Fig. 5. The Electronic Voltmeter used for measurement of reactance.

procedure is similar to the above described procedure for the measurement of capacitors. To calculate the inductance of a coil, however, the formula: $L = \frac{R}{\omega}$ should be used.

For the measurement of the numerical value of the impedance as well as the

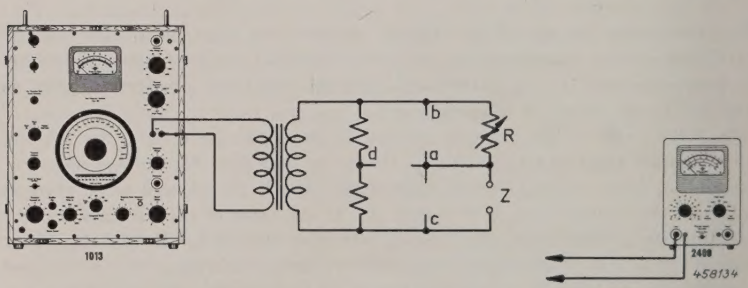

Fig. 6. Measuring arrangement for impedance and phase angle measurements.

phase angle, the bridge arrangement shown in Fig. 6 may be employed. Using the Electronic Voltmeter for indication, the resistor R is adjusted till the voltage across ab is equal to the voltage across ac. Then the numerical value of the unknown impedance, z, is equal to the resistance R.

When measuring the voltage across ad and the voltage across bd, the phase angle φ of the impedance z can be calculated from the equation: $\tan \varphi/2 = \frac{ad}{bd}$.

Checking Amplification and Frequency Response.

The amplification, attenuation, and frequency response of amplifiers, filters etc. can be readily checked by means of the Electronic Voltmeter Type 2409. The voltmeter is used to measure the input as well as the output voltages.

By reading the two values off the Voltmeter db-scale in connection with the db-scale of the calibrated attenuator, the input and output voltage is expressed in db above 1 volt. By subtracting the input value from the output value, the amplification (or attenuation) is found directly in db.

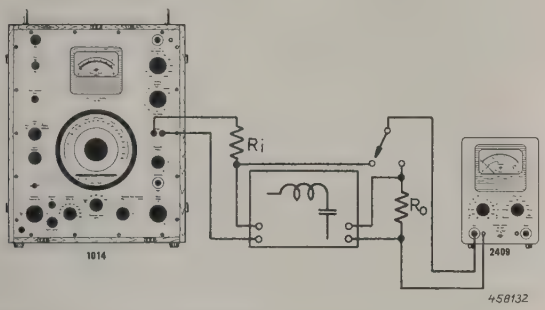

Fig. 7. Measurement of amplification and frequency response of amplifiers, filters etc.

The frequency response of a four-terminal network can be checked when an arrangement as shown in Fig. 7 is used.
A BFO Type 1014 is used as signal source, and the Electronic Voltmeter as indicator. The resistors R_i and R_o should match the input and output impedance of the network under test. As the frequency of the BFO is varied, the input and output voltages can be read off the meter scale, and noted down for a certain number of predetermined frequencies. From the table thus obtained the frequency response curve can be drawn.

The Electronic Voltmeter used as Calibrated Amplifier.
The Electronic Voltmeter is supplied with an output jack, by means of which it is possible to use the instrument as a calibrated amplifier. In order to calibrate the instrument to have an amplification of exactly 60 db, the input terminal should be connected to the output terminal by means of a short cable. With the range switch in position 0 db, the sensitivity adjustment on the back cover of the instrument is rotated, until the amplifier just starts oscillating. This is indicated on the meter as the point where the meter pointer suddenly moves from a position slightly above zero to full deflection.
When this adjustment is completed the attenuator scale can be used for reference, i.e. when the attenuator switch is set to —10 db, the amplification is 10 db, when the attenuator switch is set to —20 db, the amplification is 20 db etc.
When the instrument again should be used for voltage measurements, the sensitivity is readjusted by means of the built-in reference voltage, as described under "Operation" page 6.

Distortion Measurements.

The non-linear distortion in four-terminal networks is normally expressed by means of the formula:

$$d = 100 \sqrt{\frac{A_2^2 + A_3^2 + A_4^2 + \dots}{A_1^2 + A_2^2 + A_3^2 + \dots}} \% \simeq 100 \frac{\sqrt{A_2^2 + A_3^2 + A_4^2 + \dots}}{A_1} \%.$$

The factor d can be measured directly when the Electronic Voltmeter Type 2409 is used in connection with the Frequency and Distortion Measuring Bridge Type 1607, as shown in Fig. 8.

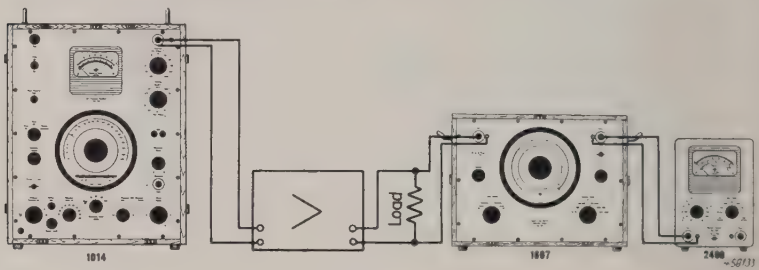

Fig. 8. Measuring arrangement for distortion measurements.

Type 1607 is basically a variable blocking network, by means of which any frequency in the range 20 c/s to 20000 c/s can be attenuated by more than 80 db.

To measure the factor d the complete output signal from the network under test should first be fed to Electronic Voltmeter Type 2409, and the amplification adjusted until the meter pointer gives maximum deflection on the meter (10 on scale). The measuring frequency is then rejected by means of Type 1607, and the reading on the Electronic Voltmeter is now the factor d %.

Note: *The "Meter Switch" on Type 2409 must be switched to measure the RMS value of the signal.*

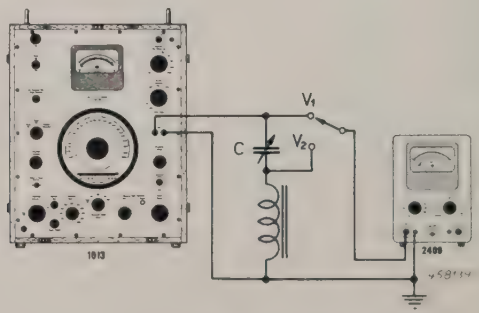

Fig. 9. Measurement of quality-factor of inductances.

Measuring the Quality Factor of Inductances.

The quality factor Q of a self-inductance is of interest in many cases, for example when developing audio frequency filters. Fig. 9 shows how it can be measured with the Electronic Voltmeter Type 2409. With the aid of a low-loss capacitor C the measuring circuit is brought into resonance at the measuring frequency used. The ratio of the two voltages, measured in the two positions of the switch, is the desired Q-value, $Q = \frac{V_2}{V_1}$. It is a condition that $Q \cdot \frac{1}{\omega C} << 10\ M\Omega$.

Measurements using the dbm-scale.

Level measurements on AF-transmission lines, telephone lines etc. can be carried out by means of the Electronic Voltmeter Type 2409 when the dbm-scale is used. The dbm-scale is designed in such a way that a deflection of 0 dbm corresponds to a power level of 1 mWatt developed in a resistance of 600 ohms, the voltage reference thereby being 0.775 volts.

When the dbm-scale is used in conjunction with the calibrated attenuator, it is possible to measure power levels from —60 to +62 dbm.

To measure the power level of a transmission line the instrument is connected directly across the line, and the level can be read off the dbm-scale, provided that the line impedance is 600 ohms. As the instrument has a high input impedance, the parallel load obtained by means of the instrument will not influence the operating conditions of the measuring object.

Often the instrument is used for measurements on lines with an impedance different from 600 ohms.

In such cases the reading obtained on the dbm-scale no longer represents the power level in dbm. The reading then obtained is the voltage level in db above 0.775 volts, and should preferably be referred to as "db re 0.775 volts".

Appendix

Meter Damping Characteristics and VU Measurements.

The Electronic Voltmeter Type 2409 is provided with two different meter damping characteristics. When the "Meter Switch" is set to "Low Damping" and "Average" measurements, the damping and rectifier characteristics are in accordance with the standards for vu-measurements as specified in ASA C. 16.5-1954.

As the standards require an instrument, which is calibrated in RMS values and which has rectifier characteristics corresponding to those used for the measurement of arithmetic average values, a special calibration mark on the dbm-scale is provided. *For vu-measurements the sensitivity should thus be adjusted till the meter pointer deflects to the red mark on the dbm-scale,* when the range switch is in its ref. position.

This means that "Volume", which is defined as "the dynamic magnitude of complex audio-frequency electrical waves such as occcur in speech and music", can be measured by reading off the dbm-scale directly. With the range switch in position 0 db/10 V, a deflection of 0 dbm corresponds to 0 vu, which is equal to 1 mWatt in 600 ohms. When the range switch is turned to any other position, the indicated attenuation in db should be added to the value read off on the meter dbm-scale in order to give the level in vu. The correct vu reading is determined as "the greatest deflection occuring in a period of about a minute for program waves, or a shorter period (e.g. 5 to 10 seconds) for message telephone speech waves, excluding not more than one or two occasional deflections of unusual amplitude".
Note: The "Peak" position of the "Meter Switch" is not suitable for vu-measurements.

Some Notes on the Arithmetic Average, RMS and Peak Rectifier.
The "Value" of an AC signal may be expressed as the *arithmetic average value* of the signal normally defined by the expression:

$$S_{a.a.} = \frac{1}{T} \int_{o}^{T} | s(t) | \, dt$$

where T is the time interval between two successively following moments of equal phase, see Fig. 10.
A second method of expressing the value of the signal is by means of its *root mean square* (r.m.s.) *value* defined by:

$$S \text{ r.m.s.} = \sqrt{\frac{1}{T} \int_{o}^{T} (s(t))^2 \, dt}$$

Finally, it is sometimes desired to know the maximum value that the signal may reach within a certain time interval (a period), and this value is known as the *peak value* of the signal.
Fig. 10 indicates the significance of the above definitions with regard to a periodic signal of period T.
To obtain a meter indication on a measuring instrument which is designed to measure AC signals over a wide frequency range some sort of rectifier arrangement must be incorporated in the circuit. The rectifier then transforms the A.C.-signal voltage into the DC voltage necessary to feed a moving coil meter.
It is now possible to give the rectifier circuit characteristics making the meter indication proportional to any one of the above mentioned "values" of the AC input signal.
Most vacuum tube voltmeters measure the arithmetic average value; the rectifier circuit employed in Type 2409 is designed, however, to enable not only the measurement of the arithmetic average, but also the true r.m.s. and the peak value of A.C. signals in the frequency range 2 to 200000 c/s.

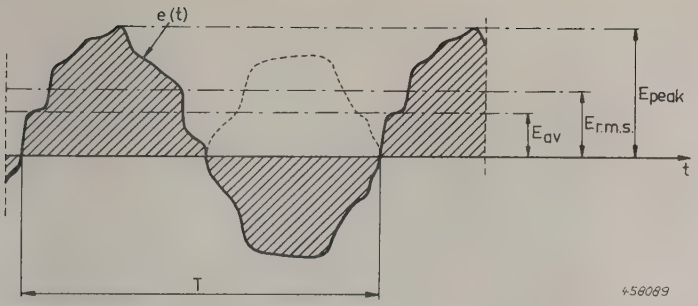

Fig. 10. Example of a periodic signal with indication of the peak, r.m.s. and arithmetic average value of the voltage.

In nearly all practical applications of the voltmeter the r.m.s. indication will be the most important type of indication, because it has a direct connection to the energy contents of the signal being measured.
However, the possibility of measuring both the r.m.s. value and the arithmetic average value of complex signals is also of considerable interest in normal laboratory work. It is, for instance, possible by means of Type 2409 to establish correction factors for simple average type indicating voltmeters when applied to certain specific measurements of complex signals.
The measurement of signal peak values is convenient when the limiting effects of non linear electronic components are investigated.
Furthermore, from the measurement of the peak, the average and the r.m.s. value of a periodical signal the crest factor and the form factor of the signal can be calculated.
The crest factor is defined as:

$$\text{fc} = \frac{\text{S peak}}{\text{S r.m.s.}}$$

and the form factor:

$$\text{ff} = \frac{\text{S r.m.s.}}{\text{S average}}$$

From these expressions are readily seen that the crest factor of sharp periodic pulses must be high, while the crest factor, as well as the form factor for an ideal square-wave is exactly 1. It is thus possible, in some cases, by means of the crest factor and the form factor to obtain a rough picture of the signal wave shape.

Specification.

Frequency Response: Linear to within ± 0.2 db RMS from 2 c/s to 200000 c/s.

Voltage Ranges: Full deflection for 10 — 31.5 — 100 and 315 mV and for 1 — 3.15 — 10 — 31.5 — 100 — 315 and 1000 volts.

Input Impedance: 10 MΩ parallelled by 20 μμF.

Accuracy: accuracy of attenuator better than 2 % at 1000 c/s, accuracy of meter scale better than 1 % of full scale deflection.

Stability: The instrument is stabilized for line voltage variations. For a 10 % variation in line voltage the meter deflection will change less than 2 %.

Sensitivity Adjustment: The instrument is supplied with a built-in reference voltage. The reference voltage will vary less than 0.5 % for a line voltage variation of 10 %.

Meter Indication: By means of a switch the instrument can be adjusted to read peak, arithmetic average or true r.m.s. values. Accuracy of RMS indication is 0.5 db for signals with crest factors up to 5.

Meter Damping: The meter is provided with two damping characteristics, one which is in accordance with the standards for VU-measurements, and one which has a high damping suitable for measurements of low frequency signals.

Scales: The scale is illuminated and graduated in volts from 0 to 10 V and from 0 to 31.5 V. Furthermore, in db above 1 volt (0 — 20 db) and in dbm, which is here defined as db re 0.775 V (0 — 22.2 dbm).

Output Impedance: Approx. 50 ohms, in series with 25 μF.

Amplification: Max. 60 db.

Distortion: Less than 0.2 % with an output voltage of 10 Volts.

Hum and Noise: With open circuit input and maximum amplification the hum and noise level is equivalent to less than 100 μvolts at the input terminals, and it is equivalent to less than 20 μvolts with short circuited input terminals.

Tubes: 12AX7 (ECC83), 6U8 (ECF82), 6X4 (EZ90), and OA2.

Power Supply: 115 — 127 — 150 — 220 — 240 volts, 40 — 400 c/s. Consumption approx. 28 W.

Dimensions:

Dimensions excl. dials and knobs.	Height	Width	Depth
Centimetres	26	18	13
Inches	10	7	5
Weight	4.5 kg		10 lbs.

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